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ONION STORAGE TEMPERATURES AND KEEPING QUALITY - C V Smith

1. INTRODUCTION

Given that an automatic ventilation (cooling) system is feasible for onion bulks and given information on the range and duration of temperatures likely to be achieved in bulks in the Eastern Region, we may move on to the underlying, basic question and study the implication for the keeping quality of the onions stored.

The information presented in this note falls into 2 parts. One is a summary of the temperatures likely to be experienced in ventilated onion bulks in a typical sample of seasons. The temperature data of Ag Mem. 630 (7 seasons at Mepal) are integrated in some convenient way, along the lines set out in Ag Mem. 622, to indicate the progress and accumulation of "metabolic change units" in the "average" season. The second part of the information concerns the observed keeping quality (degree of sprouting) in the 1973-74 storage season and its dependence upon harvest date, treatment with inhibitor and the temperature accumulations in store during winter

When both parts are brought together, we may infer for the "average" season the advantages and likely outcome of a cooling automatic ventilation system which blows the onions at every convenient opportunity.

2. ONION BULK TEMPERATURES IN THE AVERAGE SEASON

A method of analysis of onion bulk temperatures for our purpose has been suggested in Ag Mem. 622. In the memorandum, temperature and the time for which it was effective was used to establish a measure of the "metabolic change" over the period and accumulated metabolic change was related to percentage sprouting of the stored onion. Among the assumptions were:-

- we deal with a first order chemical reaction;
- Q_{10}, the ratio of the reaction rates at temperatures differing by 10 deg C, was 2.5;
- the reaction rate always increased with temperature over the range of temperatures likely to be experienced;
- a linear interpolation between intermediate temperatures could be adopted.

In the present analysis a number of variations on the basic procedure were examined, including:-

- 2 temperature bases, $0^{\circ}C$ and $6^{\circ}C$;
- 2 values of Q_{10}, 2.5 and 2.0;
- linear interpolation at intermediate temperatures and also the exponential interpolation more appropriate to first order chemical reaction rates.

The data used were the inferred bulk temperatures (given an automatic ventilation system) at the Arthur Rickwood EHF, Mepal, over the past 7 seasons - cf Ag Mem. 630. Results are shown for monthly intervals in general; conventional Degree Day units were also calculated.

The bulk temperatures at the end of a given day were used to arrive at the accumulation of (temperature and metabolic change) units for that day. Once the bulk temperature becomes controlled by the ambient, outside air temperatures and the ventilating

procedures, i.e. after the initial influence of the onion temperature at the beginning of storage has been lost, it would seem equally likely that the bulk temperatures should rise or fall from day to day, over the greater part of the storage period. It was argued that once daily temperatures were adequate for our accumulation procedures and totals over periods of the order 30 days.

Results are given in the tables below and in Figure 1. The justification for the unit adopted to produce Figure 1 (Base 0°C, Q_{10} = 2.5, linear interpolation) is given in the next section.

SEASON 1973-74

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1973	October	225	51	67	23	54	21	62	22	52	20
	November 1-15	121	1	27	3	42	3	44	3	40	0,
	16-30			21							
	December	99	0	46	0	41	0	42	0	39	0
1974	January	136	0	51	2	45	2	47	2	42	2
	February	123	0	47	2	40	2	42	2	38	2
	March	153	6	54	8	46	8	49	7	44	7
	April	189	20	58	21	49	20	54	20	47	19
	May	265	43	73	38	59	34	69	35	57	33

SEASON 1972-73

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1972	October	265	82	72	40	58	36	69	37	56	34
	November 1-15	157	27	31	14	46	13	50	13	44	12
	16-30			23							
	December	134	1	51	3	44	3	46	3	42	3
1973	January	105	0	47	0	41	0	42	0	39	0
	February	94	0	42	0	37	0	38	0	35	0
	March	126	0	50	0	43	0	45	0	41	0
	April	160	7	54	10	46	10	49	10	44	9
	May	276	91	78	43	61	38	72	40	58	37

SEASON 1971-72

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1971	October	265	81	73	40	59	36	69	37	57	35
	November 1-15	142	11	28	8	44	7	47	7	42	7
	November 16-30			23							
	December	172	22	57	18	48	17	52	17	46	17
1972	January	113	1	48	2	42	2	43	2	40	2
	February	119	0	47	0	41	0	42	0	39	0
	March	145	3	53	4	45	4	48	4	43	4
	April	203	32	60	30	49	28	55	28	47	27
	May	294	108	80	47	62	42	75	43	60	40

SEASON 1970-71

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1970	October	263	75	73	41	58	38	69	39	56	36
	November 1-15	194	29	31	18	50	17	55	17	47	16
	November 16-30			29							
	December	106	6	47	6	42	6	43	5	40	5
1971	January	113	0	48	3	42	3	44	3	40	3
	February	111	0	45	0	39	0	40	0	37	0
	March	124	0	50	0	43	0	45	0	41	0
	April	186	13	59	18	49	17	54	17	47	17
	May	262	84	73	38	59	33	69	34	57	32

SEASON 1969-70

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1969	October	364	178	99	58	73	49	91	53	70	46
	November 1-15	150	20	31	12	45	11	49	11	43	11
	16-30			22							
	December	86	0	44	0	40	0	40	0	38	0
1970	January	111	0	47	0	42	0	43	0	40	0
	February	85	0	42	0	37	0	38	0	36	0
	March	90	0	44	0	40	0	41	0	38	0
	April	150	9	52	11	45	11	48	11	43	11
	May	364	178	99	58	73	49	91	53	70	46

SEASON 1968-69

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1968	October	382	196	105	60	76	51	97	56	73	48
	November 1-15	173	24	29	17	48	16	52	17	45	16
	16-30			28							
	December	89	0	44	0	40	0	41	0	38	0
1969	January	133	5	51	6	44	5	46	5	42	5
	February	53	0	36	0	33	0	33	0	32	0
	March	105	0	47	0	41	0	42	0	39	0
	April	161	10	54	11	46	10	49	10	44	10
	May	328	142	89	52	67	45	83	48	65	43

SEASON 1967-68

Interpolation		Accumulated Day Degrees		Accumulated metabolic change units							
		-	-	Linear				Exponential			
Q_{10}		-	-	2.5		2.0		2.5		2.0	
Base		0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C	0°C	6°C
1967	October	327	141	90	52	68	45	84	48	65	43
	November 1-15	127	0	25	1	43	1	44	1	40	1
	16-30			24							
	December	110	2	67	4	42	4	43	4	40	4
1968	January	101	0	46	1	41	1	42	1	39	1
	February	85	0	42	0	37	0	38	0	36	0
	March	113	2	48	2	42	2	44	2	40	2
	April	177	35	57	20	48	19	53	19	46	18
	May	239	53	67	36	55	33	63	33	53	32

3. KEEPING QUALITY IN THE 1973-74 SEASON

A number of onion samples from a spread of farms and harvest dates, with and without sprout inhibitor applied, were held in a common store during the 1973-74 season. The bulk was blown at intervals to control the temperature. Bulk temperature was recorded from time to time and percentage sprouting was recorded at longer periods under the various treatments. All samples were of the main crop Rijnsburger type.

From the onion bulk temperatures observed, an estimate was made of all of the accumulated (temperature and metabolic change) units examined in the previous section for this real situation.

Some results are shown in Figure 2 for the sample that was harvested late (late October to early November) and to which no sprout suppressant (maleic hydracide) was applied.

In Figure 2, the observation that sprouting increased with time, for example from 14% to 30%, with no corresponding increase in accumulated Day Degrees above a base of 6°C, is an argument for the adoption of a base lower than 6°C and also an indication that some other method of temperature integration is perhaps to be preferred.

Comparison, in Figure 2, of the metabolic change units calculated suggests no reason why one should be preferred to another.

An examination of data relating to a more conventionally treated sample, with harvest in early September and with sprout suppressant applied, led to much the same general conclusions. All subsequent data analysed in this note are presented in terms of metabolic change units above a base of 0°C, with Q_{10} = 2.5 and with linear interpolation. The starting point for the accumulation of such units has been taken to be mid-November, both in Figure 2 and in later diagrams, since the evidence is that it is difficult to break dormancy by any treatment before this time.

The storage results achieved from crops taken at 3 harvest dates are shown in Figures 3, 4 and 5. From these figures, we may conclude that:-

(i) Though practically every sample shows a steady increase in numbers sprouting with time (and therefore with accumulated temperature or Metabolic Change (MC) units), there are some samples which do not break dormancy to any marked degree.

This result would appear to be independent of the time of harvest.

If this non-sprouting property is to be attributed to treatment and not to some inherent biological characteristics, eg sterility, then there is no way of differentiating between sprouting and non-sprouting samples on the information made available. We are not in a position, for example, to assess independently the effectiveness of the spray application of sprout suppressant in the field for our stored samples.

(ii) The probability of apparently sterile bulbs in each sample, and their numbers, would go some way to explaining the observed tapering off with some samples (Figure 3) of the percentage sprouting with time.

(iii) The order of increase of percentage sprouting with increase of accumulated Metabolic Change units (above some threshold value) would appear to range from:

an additional 1% sprouting for each 5 MC units - Figure 3(i)
- " 4
- " 5;

to an additional 1% sprouting for each 12-15 MC units

- Figure 3(ii)
- " 5.

Figures 3 to 5 show only observed values. On the basis of these diagrams, linear exterpolation to the 10% level of sprouting would seem reasonable.

If we concentrate on the more commonly observed higher rate of change of sprouting (1% per 5 MC units) then we find:-

HARVEST PERIOD	ACCUMULATED MC UNITS FOR 10% LEVEL OF SPROUTING
Early September	
with sprout suppressant	240
no sprout suppressant	250
Late September/early October	
with sprout suppressant	190 - 330
no sprout suppressant	290
Late October/early November	
with sprout suppressant	175 - 270
no sprout suppressant	195 - 280

In view of the great variability shown and the overlapping between the results for onion samples sorted here according to harvest date, a quantitative statistical comparison is scarcely justified.

The consequences of applying sprout suppressant are difficult to demonstrate.

(iv) The omission of sprout suppressant would in general appear to have no effect on the rate of increase of sprouting, with MC units and with time (Figures 3, 4 & 5) though in one of the 2 non sprayed samples at a late harvest (Figure 5) the omission of sprout suppressant was associated with a rate of sprouting twice that more commonly observed.

On the very limited evidence brought together here, the efficacy of the sprout suppressant (which would appear to range from zero to 100% in the samples examined), or at the very least current methods of application, and certainly the general economic justification for suppressant application must be questioned. With 3 of the untreated samples (Figures 3, 4, 5), the extent of sprouting at any point in time falls well within the range demonstrated by other treated samples. With the remaining untreated samples (Figure 5) there would appear some advantage in suppressant application.

4. IMPLICATIONS OF THE 1973-74 SEASON DATA FOR THE GENERAL CASE

An economically acceptable precentage sprouting is taken here to be 10%. At this level, hand sorting when the bulk is broken open is still a practical proposition.

The primary interest in all this work lies in the values of the MC units accumulated up to the time that this limiting 10% level is reached.

Application of the results of the 1973-74 season to the general situation represented by Figure 1 suggests:-

(i) Onions from any harvest date later than September (whether treated with sprout suppressant or not) might be expected to reach the 10% level of sprouting, in an automatically ventilated store in the Eastern Region, from early March onwards.

(ii) An extention of this safe storage period well into May is certainly possible (as evidenced by the remaining data of Figures 3, 4 & 5). This extension is presumably dependent in no small measure on the efficiency of the sprout suppressant procedures.

This information is summarised in Figure 6.

5. DISCUSSION

The field and storage data have been grouped according to treatment, ie:-

harvest period;
application (or not) of sprout suppressant.

A great spread of results within and between treatments is obvious and we have to ask why this should be and what additional information might enable us to be more discriminating and to identify the factors associated with an extended safe storage.

An early consideration must be the basis of the analysis employed. Should we in fact expect a simple relationship, or even any relationship, between percentage sprouting and accumulated Metabolic Change units or accumulated Degree Days. In the limit, such

units simply reflect the progress of time and I think we can accept that there is a dependence of percentage sprouting on time in store.

If the basis for our examination is acceptable, then we must turn to the information available for grouping and differentiating between treatments.

The time of harvest, of itself, is not particularly instructive, inasmuch as it omits any statement on the crop and on the weather during the growing and field drying period. Factors of this kind are presumably relevant to crop maturity and keeping quality; information of the following kind would presumably be of interest in a more detailed analysis:-

- a quantitative assessment of weather (including soil moisture) during the growing season
- a quantitative assessment of the weather over the field drying period
- some assessment of the crop at harvest, eg yield, bulb size, distribution etc
- curing time and temperatures employed.

The simple information that sprout suppressant was, or was not, applied is obviously not sufficient. The crucial need is to be able to assess the efficiency of this treatment for long term storage. Information to examine this point should include:-

- the spraying technique
- the spray dosage
- crop characteristics, eg foliar die-down, at the time of spraying
- weather on and around the spray date
- field conditions (including soil moisture) on and around the spray date.

Information of this kind is available in part from Kirton EHS Annual Reports. A superficial (non-quantitative) analysis of the results suggests that the most successful long-term storage is achieved when the weather on and after the spray date is dry and dull. A multivariate analysis, including data on the crop, the spray procedures and the weather, could conceivably indicate the preferred field conditions for satisfactory long term storage. Indeed, the spread of results shown for the 1973-74 season (Section 3 above) might suggest that any further work should be directed at this key aspect, rather than on stores and storage temperatures.

6. ACKNOWLEDGEMENTS

The field and storage data were made available through Mr P Rickard, ADAS Cambridge, and certain interested growers whose co-operation has been vital.

Meteorological Office
Cambridge
July 1974

FIGURE 1

METABOLIC CHANGE UNITS ACCUMULATED WITH TIME.

BASED ON SIMULATED ONION BULB TEMPERATURES.

EXTREME AND MEDIAN VALUES FOR 7 YEARS DATA
USING ARTHUR RICKWOOD EIFF AMBIENT AIR TEMPERATURES.

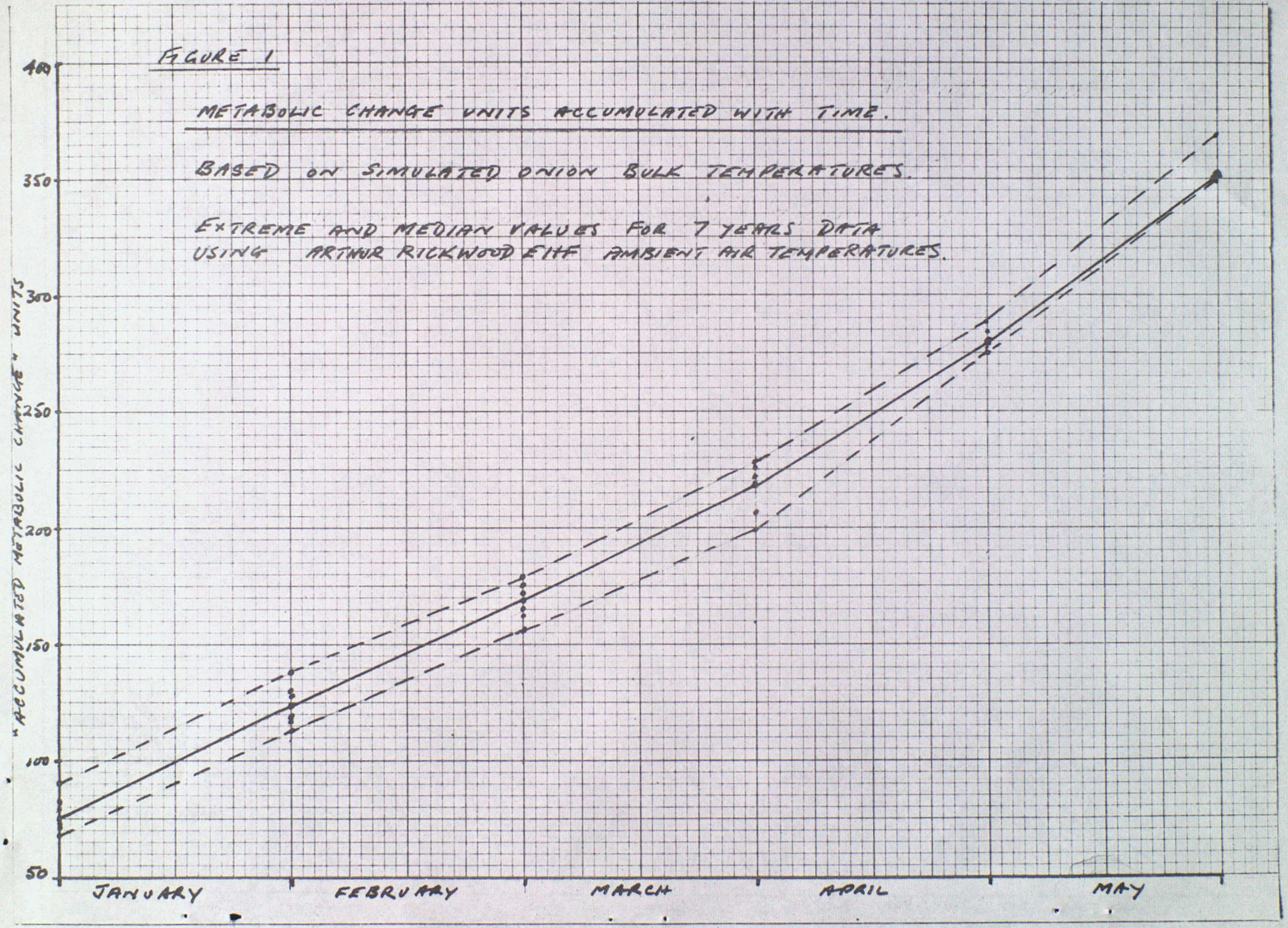


FIGURE 2 LATE HARVEST; NO SPROUT SUPPRESSANT.

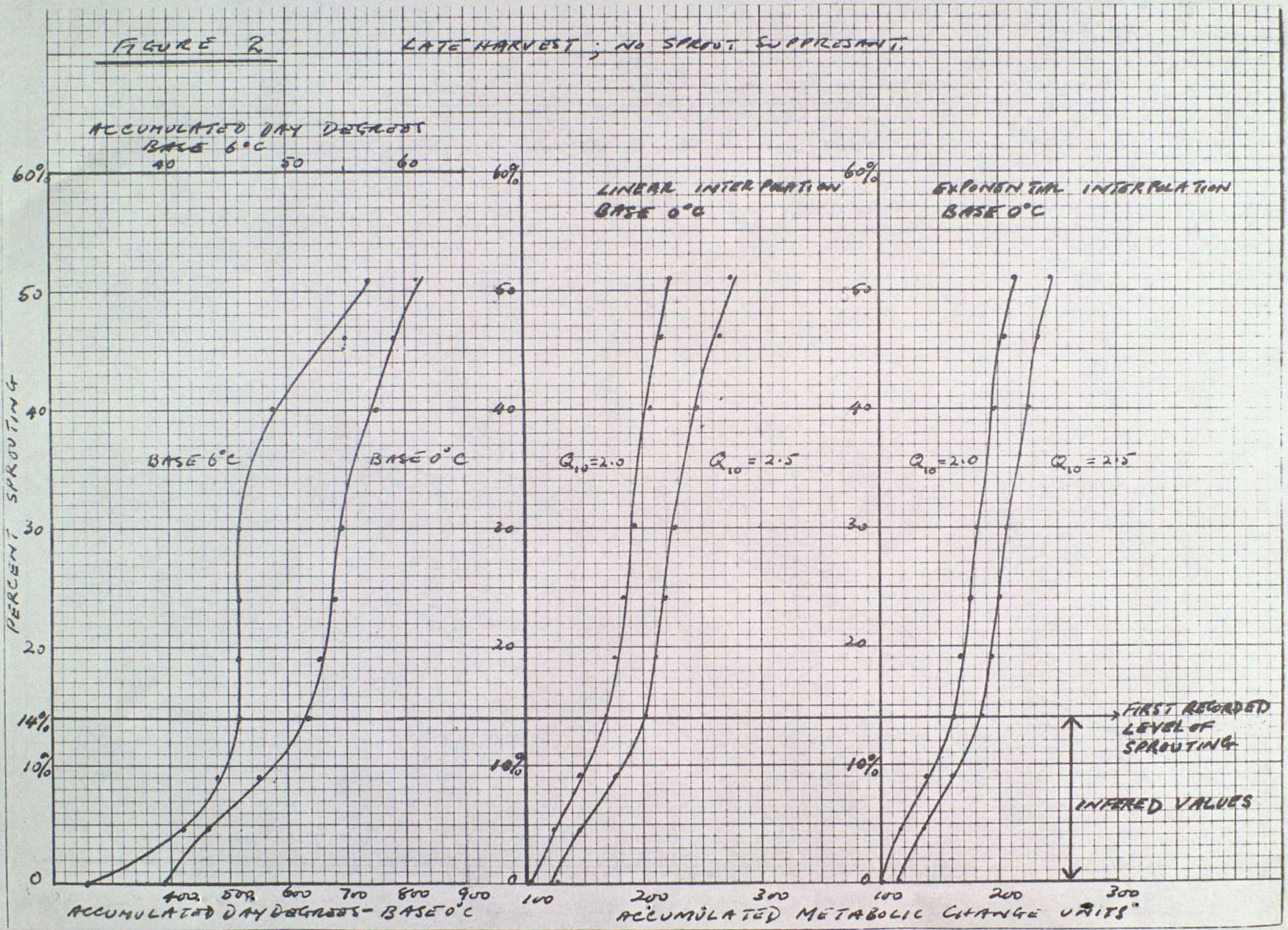


FIGURE 3

HARVEST - EARLY SEPTEMBER.

---- NO SPROUT SUPPRESSANT APPLIED.

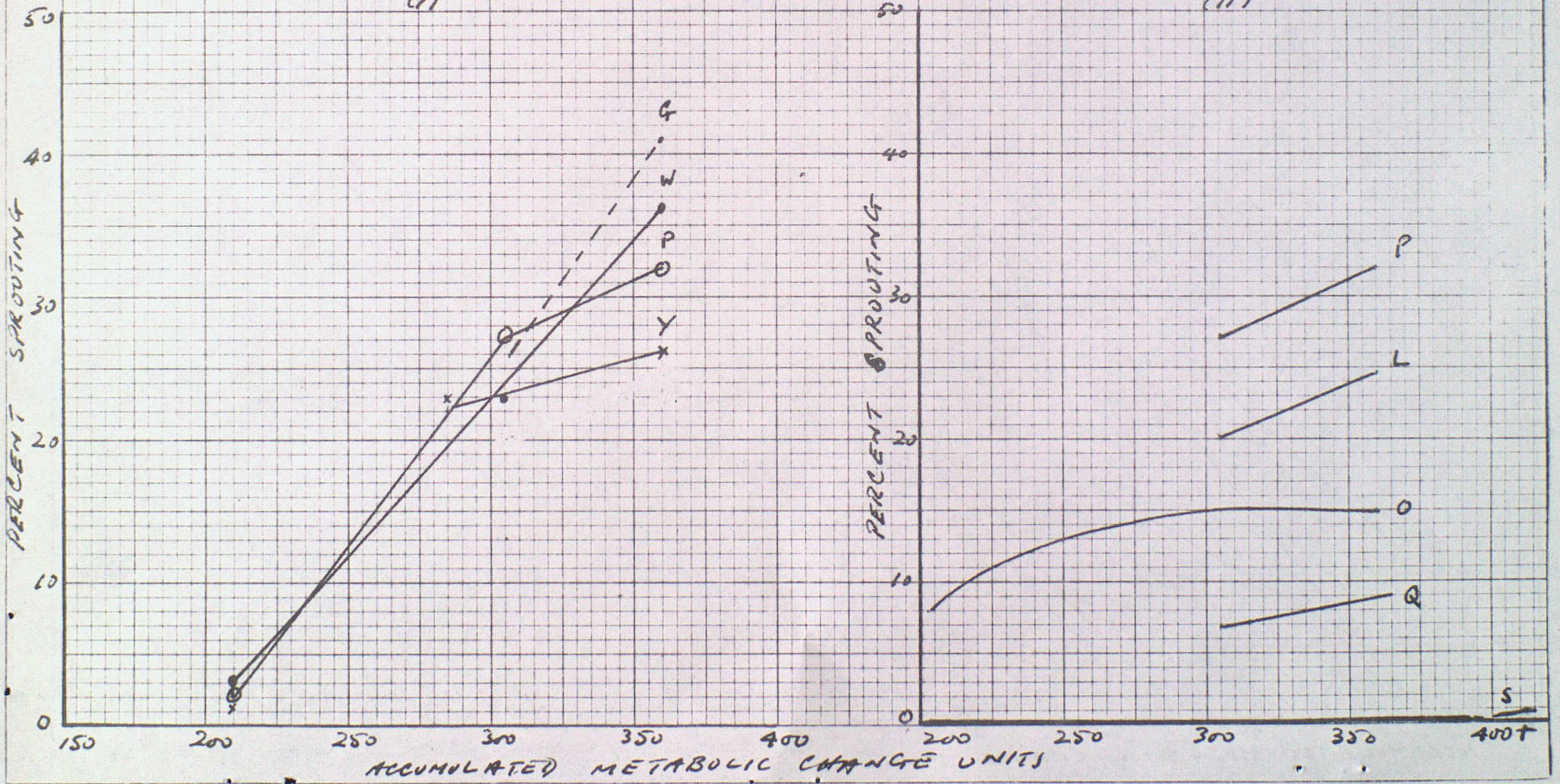
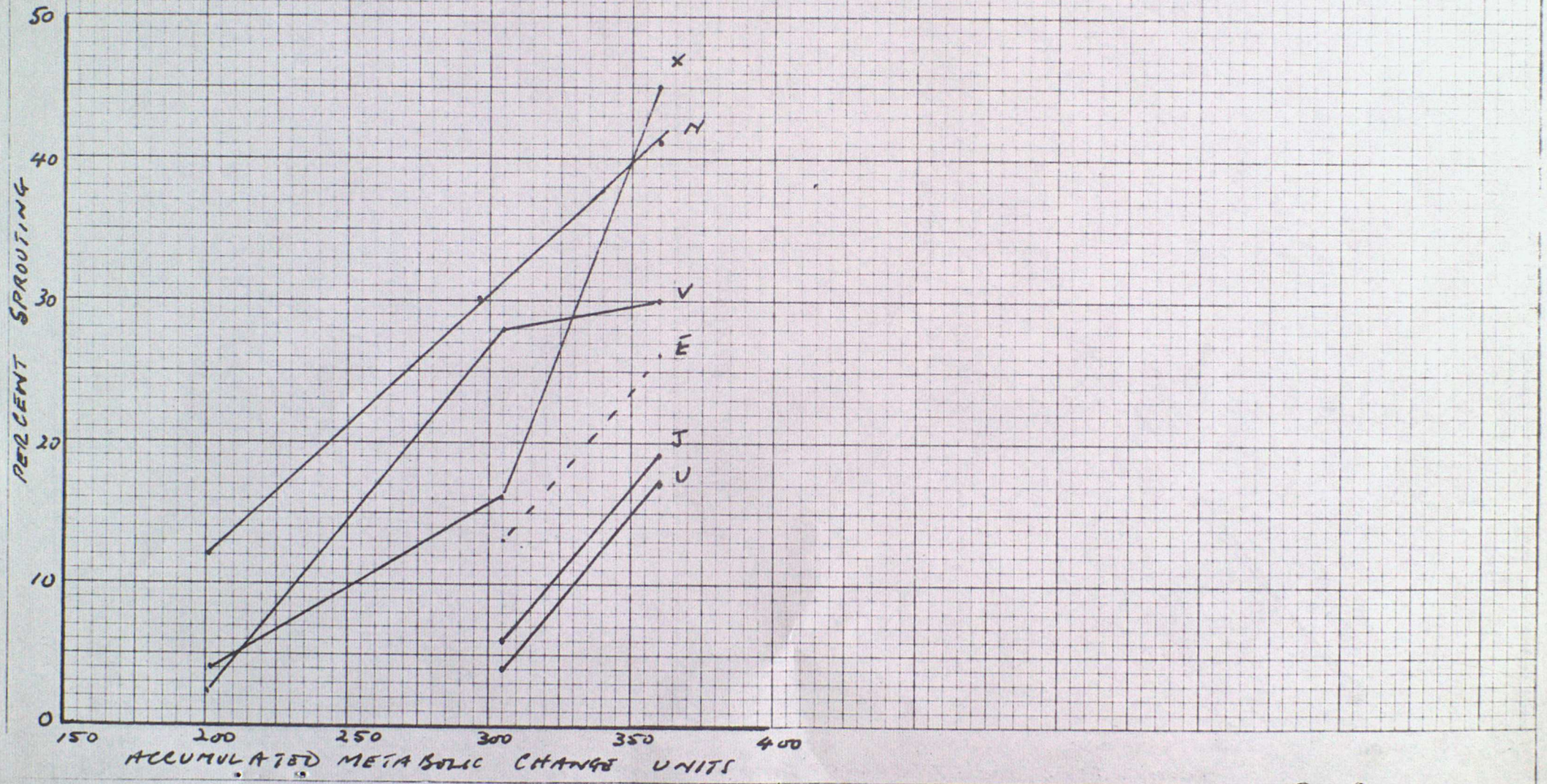


FIGURE 4

HARVEST - END SEPTEMBER / EARLY OCTOBER

---- NO SPROUT SUPPRESSANT APPLIED



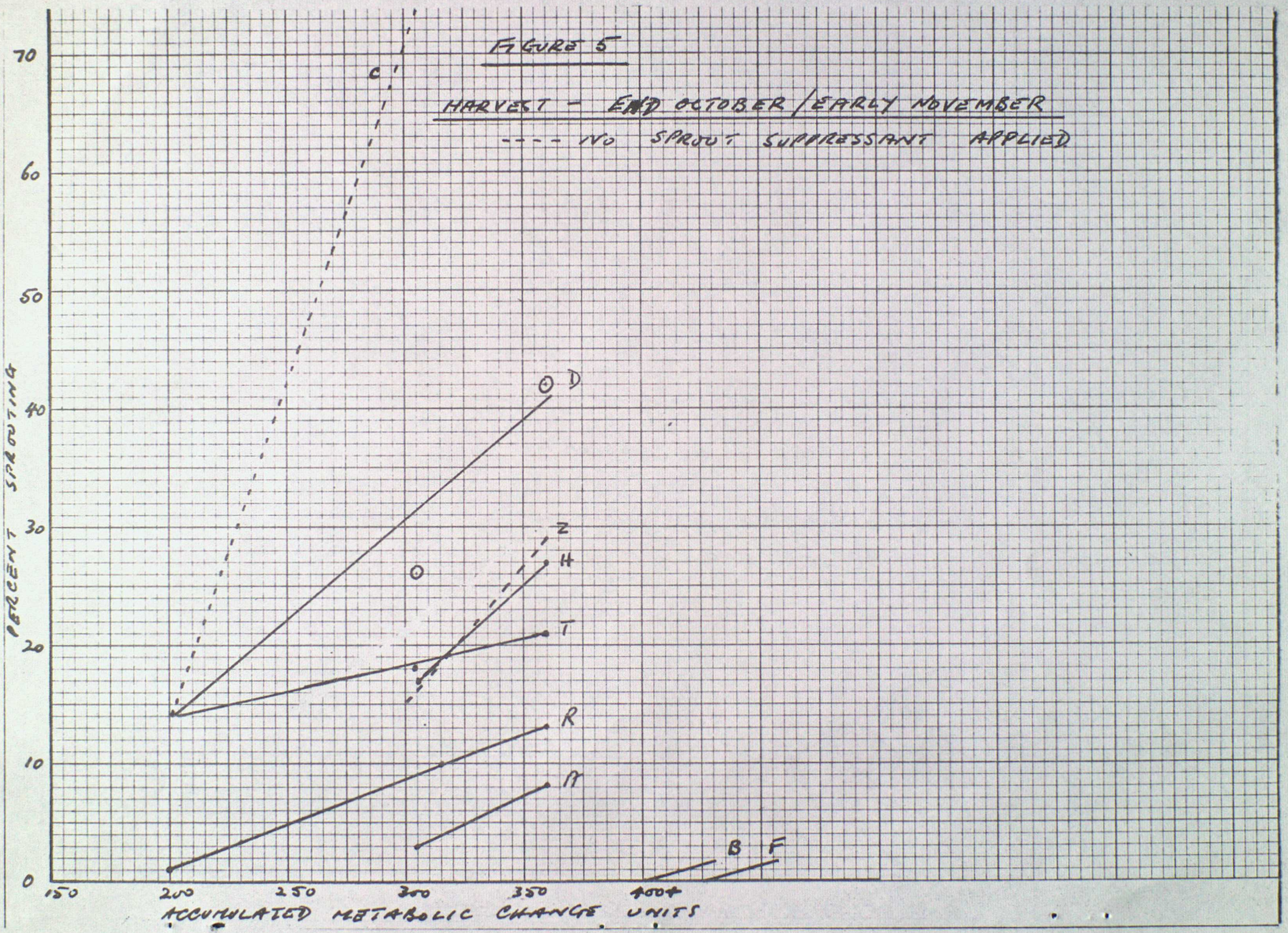
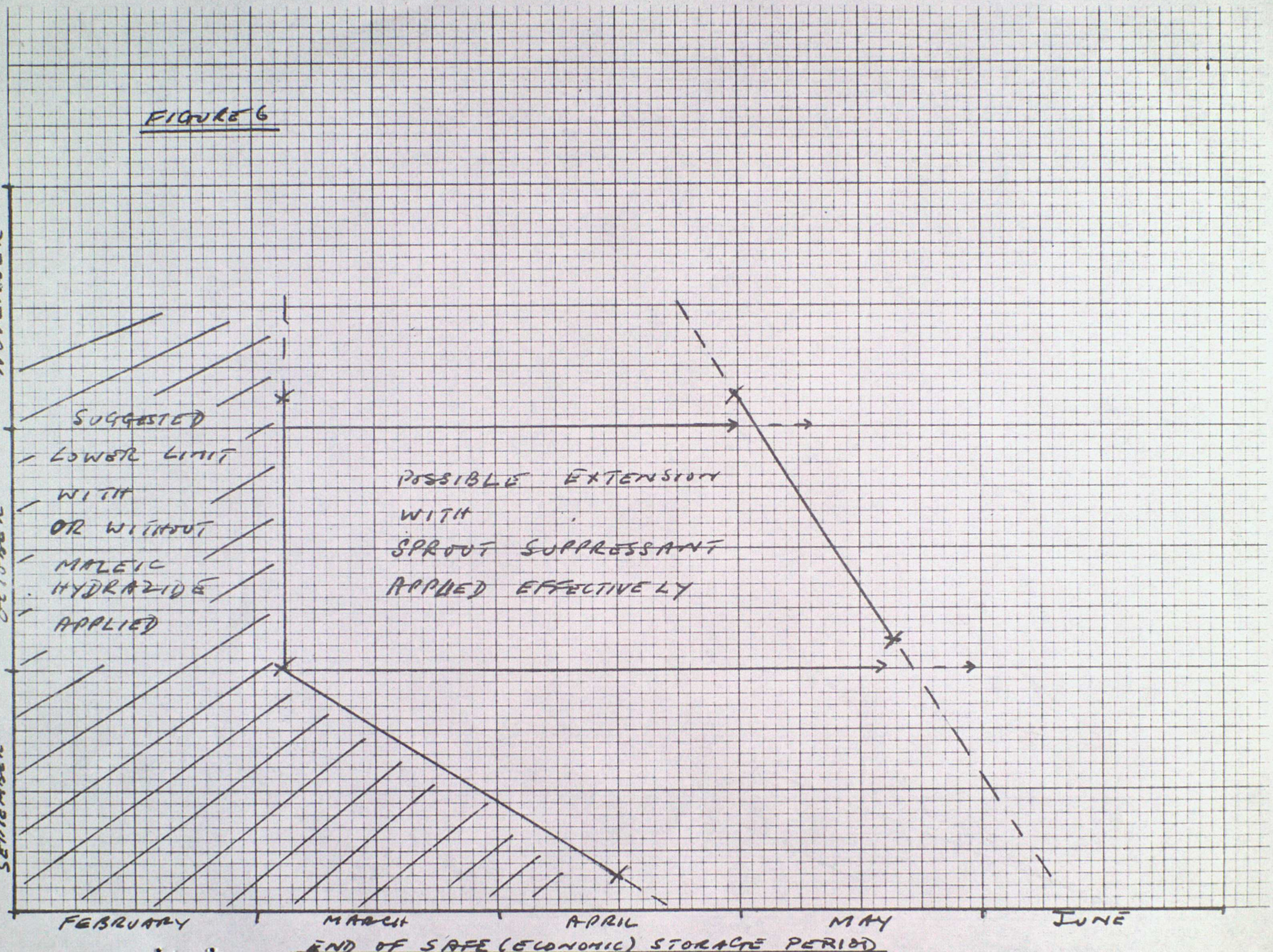


FIGURE 5
HARVEST - END OCTOBER / EARLY NOVEMBER
---- NO SPROUT SUPPRESSANT APPLIED
PERCENT SPROUTING
0
10
20
30
40
50
60
70
150
200
250
300
350
400+
ACCUMULATED METABOLIC CHANGE UNITS
C
D
Z
H
T
R
A
B
F

FIGURE 6


NOVEMBER
OCTOBER
SEPTEMBER
HARVEST PERIOD
SUGGESTED LOWER LIMIT WITH OR WITHOUT MALEIC HYDRAZIDE APPLIED
POSSIBLE EXTENSION WITH SPROUT SUPPRESSANT APPLIED EFFECTIVELY
FEBRUARY
MARCH
APRIL
MAY
JUNE
END OF SAFE (ECONOMIC) STORAGE PERIOD